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STATISTICAL ANALYSIS
FOR
REGULATIONS AND CONTROL
OF
MUNICIPAL WASTEWATER EFFLUENTS

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MINISTRY OF
TREASURY AND
ECONOMICS

CENTRAL
STATISTICAL
SERVICES

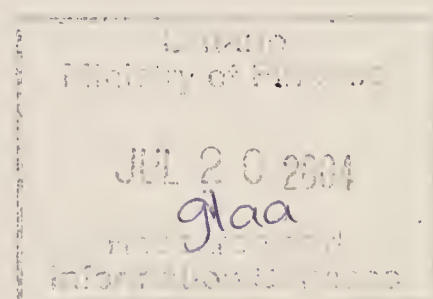
OCTOBER 1980

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STATISTICAL ANALYSIS FOR REGULATIONS AND CONTROL OF MUNICIPAL WASTEWATER EFFLUENTS

REPORT PREPARED FOR THE
MINISTRY OF THE ENVIRONMENT



Ontario

MINISTRY OF
TREASURY AND
ECONOMICS

CENTRAL
STATISTICAL
SERVICES

OCTOBER 1980

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1. INTRODUCTION

In early 1979, Central Statistical Services analyzed effluents from six waste water treatment plants to find the sample size needed to determine plant performance on an annual basis. (1) One year of daily composite data for six plants was used to estimate sampling size. It was found that effluent BOD and SS vary over a large range of values. Data collected for these plants does not follow any parametric distribution. In addition, time series analysis and analysis of variance, were performed on data to test variation between plants and between months. It was concluded that a non-parametric method would give us a reasonable estimate and the sampling size to monitor the program.

It was suggested in that study that more data and more detailed information about the plants must be analyzed to develop a program for monitoring purposes. This report contains all the steps taken (from December 1979 to March 1980) towards analyzing the Municipal Wastewater Treatment Plant data to develop regulations and control of wastewater effluents.

2. PURPOSE

There are two basic objectives of this study:

- i) To determine the minimum number of samples that need to be taken at the treatment plants, in order to be able to assess the effluent quality with respect to BOD₅ and SS with confidence limits of over 90%. Conversely, to determine the limits of confidence if the number of samples were to be restricted to one/month.
- ii) To specify effluent quality control standards for new plants, based on the analysis of the plants in individual "group" or "cell" (defined as follows).

(1) See page 57, Reference 6(A).



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It was decided to analyze the data for the last five years and the data will be divided into groups (or cells) consisting of plants of specified capacities and type of treatment provided. For the initial analysis, the following water pollution control plants size ranges were chosen:

- i) ≤ 1 mgd
- ii) >1 mgd and ≤ 10 mgd
- iii) >10 mgd.

The treatment types were the same as per classification in Ministry of the Environment Operations Manual, e.g.,

- i) Primary Treatment Plants
- ii) Conventional Activated Sludge Plants
- iii) Extended Aeration Plants
- iv) High Rate Activated Sludge Plants
- v) Contact stabilization Plants
- vi) Advanced Waste Treatment Plants

3. SUMMARY AND CONCLUSIONS

The BOD and SS data were obtained for the last five years from MOE. After performing detailed analysis, it can be seen in the table below that only nine cells could be constructed, out of which only seven cells could be used for sample size determination. Data from only 36 plants could be used for our analysis out of nearly 200 plants in Ontario, simply because complete data were not available for the remainder of the plants.

Number of Plants in each Cell

Type/Capacity	<1 mgd	1 - 5 mgd	6 - 10 mgd	>10 mgd
Primary Treatment Plants	2	4	-	1
Activated Sludge Plants	5	9	4	3
Extended Aeration Plants	7	-	-	-
Contact Stabilization Plants	1	-	-	-

Sample sizes were determined for each cell by using (i) Plant data and using (ii) Mean values representative of plant data. Detailed sample size tables are given in Tables VI and VII. A summary of confidence level is provided below if the number of sample size is restricted to 12 samples per year.

BOD ₅		
<u>Cell</u>	Confidence Level (with Sample Size 12 and Tolerance Error 10%)	
	All Plant Data (i)	Means Only (ii)
1. Primary Treatment Plants (< 1 mgd)	49%	99%
2. Activated Sludge Plants (< 1 mgd)	33%	60%
3. Extended Aeration Plants (< 1 mgd)	28%	60%
4. Primary Treatment Plants (1 - 5 mgd)	34%	99%
5. Activated Sludge Plants (1 - 5 mgd)	24%	24%
6. Activated Sludge Plants (6 - 10 mgd)	35%	82%
7. Activated Sludge Plants (> 10 mgd)	40%	89%

SS		
<u>Cell</u>	Confidence Level (with Sample Size 12 and Tolerance Error 10%)	
	All Plant Data (i)	Means Only (ii)
1. Primary Treatment Plants (< 1 mgd)	49%	99%
2. Activated Sludge Plants (< 1 mgd)	33%	48%
3. Extended Aeration Plants (< 1 mgd)	28%	49%
4. Primary Treatment Plants (1 - 5 mgd)	34%	85%
5. Activated Sludge Plants (1 - 5 mgd)	22%	53%
6. Activated Sludge Plants (6 - 10 mgd)	35%	70%
7. Activated Sludge Plants (> 10 mgd)	40%	91%

The following summary Table provides sample size for 90% confidence level with tolerance error of 10% for various treatment type plants. It should be noted that these sample sizes were determined for each cell by using plant data. Detailed sample size tables are given in Tables VI.

Cell	BOD ₅	Sample Size (90% Confidence Level with 10% Tolerance Error)
1. Primary Treatment Plants (< 1 mgd)	75	
2. Activated Sludge Plants (< 1 mgd)	178	
3. Extended Aeration Plants (< 1 mgd)	248	
4. Primary Treatment Plants (1-5 mgd)	159	
5. Activated Sludge Plants (1-5 mgd)	335	
6. Activated Sludge Plants (6-10 mgd)	157	
7. Activated Sludge Plants (>10 mgd)	120	

Cell	SS	Sample Size (90% Confidence Level with 10% Tolerance Error)
1. Primary Treatment Plants (< 1 mgd)	75	
2. Activated Sludge Plants (< 1 mgd)	174	
3. Extended Aeration Plants (< 1 mgd)	258	
4. Primary Treatment Plants (1-5 mgd)	158	
5. Activated Sludge Plants (1-5 mgd)	358	
6. Activated Sludge Plants (6-10 mgd)	159	
7. Activated Sludge Plants (>10 mgd)	120	

It is highly recommended that, whatever sample size is selected for each cell or cells, some general quality control limits be developed to monitor performance of these plants, and that the plants than be monitored on regular basis. It should be noted that quality control limits can be established by computing averages and standard deviations or ranges after selcting the sample size required for each cell from Tables VI and VII.

4. MAJOR ASPECTS OF STUDY AND ANALYSIS

This study is divided into five major steps. In each step the problem is presented and a brief analysis is given. Explanation and definition of statistical techniques used to analyze data are provided in the Appendix.

STEP I

Comparison of Data from Operating Summary (Green Books) and Raw Data (Black Books)

Since it was decided to analyze data for the last five years, it was found that raw data (Black Books) did not exist for all the latest years; and operating summary (Green Books) contained only monthly averages for the last five years. Before using Operating Summary data, it was decided to compare plant data to test if there was any significant difference between two sets of data from the Green Books and Black Books. Six plants from the year 1975 and eleven plants from 1976 were chosen, and BOD and SS effluents data were analyzed. Statistical tests were used to test the variances and averages. A summary of these results is given in Tables I and II.

As can be seen from the Tables, there is no significant difference between the two sets of data, hence it was concluded that data from the Green Books can be used for our purpose. The last five years Green Book data (from 1973 to 1977) were made available to Central Statistical Services in December 1979. Data were keypunched and a tape was created.

TABLE I(A)
BOD - 1975

NAME OF PLANT	SOURCE OF DATA	NO. OF CASES	S. D.	MEAN	$\alpha = .05$ HYPOTHESIS $H_0: \mu_{\text{Black}} = \mu_{\text{Green}}$
THUNDER BAY SOUTH	BLACK	9	14.577	75.000	Significant difference
	GREEN	12	21.869	102.916	
BURLINGTON DRURY LANE	BLACK	12	12.567	14.791	No significant difference
	GREEN	12	12.454	15.000	
BURLINGTON ELIZABETH G.	BLACK	11	12.366	12.554	n.s.d.
	GREEN	11	36.897	25.272	
MISSISSAUGA LAKEVIEW	BLACK	20	47.305	28.450	n.s.d.
	GREEN	12	8.436	24.416	
BURLINGTON SKYWAY	BLACK	12	5.687	7.291	n.s.d.
	GREEN	11	5.706	7.818	
MISSISSAUGA CLARKSON	BLACK	25	1.877	3.620	n.s.d.
	GREEN	12	1.215	3.750	
ALL 6 PLANTS	BLACK	89	31.286	19.523	n.s.d.
	GREEN	70	38.543	30.242	

TABLE I(A) CONT'D

BOD - 1975

NAME OF PLANT	SOURCE OF DATA	NO. OF CASES	S. D.	MEAN	$\alpha = .05$ HYPOTHESIS Ho: μ Black = μ Green
OWEN SOUND	BLACK	12	13.791	28.750	No significant difference
	GREEN	12	7.837	27.166	
MIDLAND	BLACK	13	15.518	42.846	n.s.d.
	GREEN	12	10.104	45.500	
WIARTON	BLACK	12	7.989	14.125	n.s.d.
	GREEN	10	8.003	15.500	
PORT MCNICOLL	BLACK	10	14.852	8.080	n.s.d.
	GREEN	8	8.631	6.750	
SAULT STE MARIE	BLACK	17	17.147	43.588	n.s.d.
	GREEN	12	12.993	56.583	
ALL 11 PLANTS	BLACK	153	27.554	23.741	n.s.d.
	GREEN	124	31.872	31.266	
	BLACK				
	GREEN				

TABLE I (B)

SS - 1975

NAME OF PLANT	SOURCE OF DATA	NO. OF CASES	S. D.	MEAN	$\alpha = .05$	HYPOTHESIS Ho: $\mu_{\text{Black}} = \mu_{\text{Green}}$
THUNDER BAY SOUTH	BLACK	9	20.069	75.555	No significant difference	
	GREEN	12	18.545	72.416		
BURLINGTON DRURY LANE	BLACK	12	4.827	16.250	n.s.d.	
	GREEN	12	6.112	16.416		
BURLINGTON ELIZABETH G.	BLACK	11	5.000	15.000	n.s.d.	
	GREEN	11	5.000	15.000		
MISSISSAUGA LAKEVIEW	BLACK	20	117.741	73.750	n.s.d.	
	GREEN	12	16.901	38.000		
BURLINGTON SKYWAY	BLACK	12	2.575	15.416	n.s.d.	
	GREEN	11	5.603	16.118		
MISSISSAUGA CLARKSON	BLACK	25	9.242	17.000	n.s.d.	
	GREEN	12	3.872	15.083		
ALL 6 PLANTS	BLACK	89	61.419	34.606	n.s.d.	
	GREEN	70	24.035	29.218		

TABLE I(B) CONT'D

SS - 1975

NAME OF PLANT	SOURCE OF DATA	NO. OF CASES	S. D.	MEAN	$\chi^2 = .05$	HYPOTHESIS Ho: $\mu_{\text{Black}} = \mu_{\text{Green}}$
OWEN SOUND	BLACK	12	8.919	32.500	No significant difference	
	GREEN	12	5.011	28.250		
MIDLAND	BLACK	13	22.871	43.076	n.s.d.	
	GREEN	12	28.770	52.083		
WIARTON	BLACK	12	17.726	31.250	n.s.d.	
	GREEN	10	15.129	27.000		
PORT MCNICOLL	BLACK	10	10.288	23.500	n.s.d.	
	GREEN	8	10.225	23.625		
SAULT STE MARIE	BLACK	17	13.147	53.705	n.s.d.	
	GREEN	12	5.632	47.416		
ALL 11 PLANTS	BLACK	153	48.287	36.294	n.s.d.	
	GREEN	124	22.371	32.558		
	BLACK					
	GREEN					

TABLE II (A)
BOD - 1976

NAME OF PLANT	SOURCE OF DATA	NO. OF CASES	S. D.	MEAN	$\alpha = .05$ HYPOTHESIS Ho: $\mu_{\text{Black}} = \mu_{\text{Green}}$
THUNDER BAY SOUTH	BLACK	9	35.924	70.000	No significant difference
	GREEN	12	24.711	83.916	
BURLINGTON DRURY LANE	BLACK	11	11.402	13.172	n.s.d.
	GREEN	11	6.150	8.727	
BURLINGTON ELIZABETH G.	BLACK	16	5.971	10.843	n.s.d.
	GREEN	11	6.139	12.090	
MISSISSAUGA LAKEVIEW	BLACK	15	13.265	11.500	s.d.
	GREEN	12	9.968	23.500	
BURLINGTON SKYWAY	BLACK	14	3.814	11.392	n.s.d.
	GREEN	12	5.535	13.500	
MISSISSAUGA CLARKSON	BLACK	20	7.322	4.710	n.s.d.
	GREEN	12	1.676	4.916	
ALL 6 PLANTS	BLACK	85	23.334	16.171	n.s.d.
	GREEN	70	29.924	24.842	

TABLE II(B)
SS - 1976

NAME OF PLANT	SOURCE OF DATA	NO. OF CASES	S. D.	MEAN	$\alpha = .05$	HYPOTHESIS Ho: μ Black = μ Green
THUNDER BAY SOUTH	BLACK	9	70.079	83.8889	No significant difference	
	GREEN	12	24.071	75.166		
BURLINGTON DRURY LANE	BLACK	11	21.906	15.909	n.s.d.	
	GREEN	11	18.868	16.727		
BURLINGTON ELIZABETH G.	BLACK	16	4.646	8.531	n.s.d.	
	GREEN	11	4.712	10.000		
MISSISSAUGA LAKEVIEW	BLACK	15	59.354	41.333	n.s.d.	
	GREEN	12	33.352	50.000		
BURLINGTON SKYWAY	BLACK	14	4.765	14.357	n.s.d.	
	GREEN	12	4.751	15.250		
MISSISSAUGA CLARKSON	BLACK	20	7.225	11.250	n.s.d.	
	GREEN	12	4.295	11.083		
ALL 6 PLANTS	BLACK	85	40.948	24.852	n.s.d.	
	GREEN	70	30.778	30.171		

STEP II

Analysis of data for three specified capacity groups:

- i) < 1 mgd
- ii) Between 1 and 10 mgd
- iii) > 10 mgd

The BOD and SS data were keypunched for the years 1973, 1974, 1975, 1976 and 1977 from the Green Books. All the plants which had at least seven to nine months of data were included. Plants which were not truly representative, i.e., with data less than seven months and/or continuous data less than four or five months of the whole year were excluded.

Three basic hypothesis were tested to find homogeneity of data within specified capacity groups:

- (A) Are Plant Data (BOD and SS) homogeneous within each specified capacity group?
- (B) Are Plant Data (BOD and SS) homogeneous between the plants during the same year within the specified capacity group?
- (C) Are Plant Data (BOD and SS) homogeneous between the plants within the Specified Capacity Group?

As can be seen, the hypotheses (B) and (C) are contained in the hypothesis (A). After performing Analysis of Variance on data, it was found that there is significant difference between plants in the specified capacity groups. Summary of basic statistics is given in Table III.

TABLE III

I. CAPACITY LESS THAN 1 m.g.d.

BOD 5

SS

PLANT	COUNT	MEAN	S.D.	LIMITS	COUNT	MEAN	S.D.	LIMITS
PT. EDWARD	51	64.5	35.5	54.5 to 74.5	53	62.8	68.4	43.9 to 81.5
ESPANOLA	60	63.7	35.6	54.5 to 72.8	60	61.7	23.2	55.7 to 67.7
ST. MARYS	60	6.6	4.8	5.3 to 7.8	60	5.5	3.3	4.6 to 6.2
HALIDMAN	48	8.8	8.2	6.4 to 11.1	47	26.8	16.9	21.8 to 31.7
BURLINGTON	50	20.8	21.6	14.6 to 26.9	49	21.8	40.5	10.1 to 33.4
SIDNEY T	52	13.6	12.8	10.0 to 17.0	46	21.3	25.4	13.8 to 28.8
MOORE TWP.	60	8.4	3.2	7.5 to 9.1	60	10.2	1.9	9.7 to 10.6
WESTMINSTER	58	8.3	9.5	5.8 to 10.8	58	10.5	11.8	7.4 to 13.5
ELORA	56	23.5	24.1	17.0 to 29.9	58	29.3	21.2	23.6 to 34.8
HALDIMAN	47	4.9	3.4	3.8 to 5.8	45	15.5	8.8	12.8 to 18.1
PARIS	36	15.6	10.3	12.0 to 19.0	46	27.9	21.9	21.4 to 34.3
ALLISTON	55	9.7	9.6	7.1 to 12.3	59	22.7	12.2	19.5 to 25.8
DESERONTO	57	19.0	78.5	-1.8 to 39.8	58	23.3	117.2	-7.6 to 54.0
EGANVILLE	58	10.5	15.3	6.4 to 14.4	56	17.6	11.6	14.4 to 20.6
IGNACE T	46	18.3	14.9	13.9 to 22.7	46	27.0	24.9	19.6 to 34.4
RED LAKE	42	14.5	15.4	9.6 to 19.2	43	24.8	39.7	12.5 to 37.0
MEAFORD	56	8.3	10.2	5.5 to 11.0	60	10.9	9.0	8.6 to 13.2
BRADFORD	49	17.1	13.4	13.2 to 20.8	49	47.2	99.9	18.4 to 75.8
TOTAL	941	18.9	30.9	16.8 to 20.8	953	25.7	46.8	22.7 to 28.6

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II. CAPACITY 1 TO 10 m.g.d.

BOD 5

SS

OWEN SOUND	58	34.6	10.4	31.8 to 37.3	60	32.9	13.5	29.4 to 36.3
NANTICOKE	54	87.4	91.7	62.3 to 112.4	54	61.7	58.0	45.8 to 77.4
MIDLAND	59	50.2	40.8	39.5 to 60.8	58	53.9	28.4	46.4 to 61.3
CORNWALL	53	130.6	69.6	111.3 to 149.7	58	118.7	69.9	100.3 to 137.0
PRESCOTT	59	39.1	23.7	32.9 to 45.2	59	50.7	22.2	44.9 to 56.5
FORT FRANCES	58	45.6	7.2	43.6 to 47.4	60	57.0	14.9	53.1 to 60.7
THUNDER BAY N.	16	94.2	21.9	82.5 to 105.8	16	76.9	37.4	57.0 to 96.8
CAMBRIDGE G	60	13.6	10.9	10.8 to 16.4	60	20.8	17.7	16.2 to 25.3
KINGSTON TWP.	60	59.6	51.7	46.1 to 72.9	60	63.9	59.5	48.5 to 79.2
NORTH BAY	55	22.7	12.7	19.3 to 26.1	57	32.0	21.3	26.4 to 37.6
CAMBRIDGE (PRESTON)	53	38.3	37.5	28.0 to 48.6	54	33.0	25.0	26.1 to 39.7
PARRY SOUND	58	34.0	12.7	30.6 to 37.3	59	39.6	26.9	32.5 to 46.5
CHATHAM	60	12.0	9.2	9.6 to 14.3	60	14.8	15.0	10.9 to 18.6
INGERSOL	55	9.6	5.9	8.0 to 11.1	56	14.6	14.0	10.8 to 18.3

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TABLE III (CONT'D)

II. CAPACITY 1 TO 10 m.g.d.

BOD₅

SS

PLANT	COUNT	MEAN	S.D.	LIMITS	COUNT	MEAN	S.D.	LIMITS
TILLSONBURG	55	4.3	2.4	3.6 to 4.9	60	10.9	9.3	8.5 to 13.3
WALLACEBURG	66	6.9	4.2	5.9 to 7.9	67	7.5	5.1	6.2 to 8.7
SIMCOE	47	11.9	13.1	8.0 to 15.7	48	17.4	10.4	14.4 to 20.4
WATERLOO	59	16.1	9.6	13.6 to 18.6	60	19.1	11.6	16.1 to 22.1
BURLINGTON	58	13.3	10.2	10.6 to 15.9	59	16.9	13.8	13.2 to 20.4
HALTON HILLS	52	16.4	10.6	13.4 to 19.2	60	20.7	9.6	18.2 to 23.2
BELVILLE	59	14.7	5.4	13.2 to 16.0	59	12.9	5.7	11.4 to 14.3
CARLETON	40	18.8	10.3	15.5 to 22.1	41	24.9	12.1	21.1 to 28.7
TOTAL	1194	33.0	43.1	30.5 to 35.4	1225	35.0	38.4	32.8 to 37.1

III. CAPACITY MORE THAN 10 m.g.d.

SS MARIE	60	73.0	22.7	67.0 to 78.8	60	56.0	10.1	53.3 to 58.5
BRANTFORD	60	15.5	9.1	13.1 to 17.8	60	20.5	8.2	18.4 to 22.6
KITCHENER	60	25.3	24.9	18.8 to 31.7	60	22.5	16.9	18.1 to 26.8
SUDBURY	60	15.4	8.3	13.2 to 17.5	60	15.5	8.6	13.2 to 17.6
TOTAL	240	32.3	29.8	28.5 to 36.0	240	28.6	19.7	26.0 to 31.1

STEP III

A decision was made to divide the capacity group 1-10 mgd into 1-5 mgd and 6-10 mgd respectively, and divide further these four capacity groups into treatment types, i.e., cells. Summary is provided in Table IV. The homogeneity of plant data within each cell was tested. It was observed that data were not homogeneous within each cell. Analysis of variance and range tests were performed on each cell and further groups were formed within each cell.

TABLE IV

(First Stage)

CAPACITY LESS THAN 1

BOD₅

SS

REGION	NAME OF PLANTS	CAPACITY	COUNT	MEAN	S.D.	LIMITS	COUNT	MEAN	S.D.	LIMITS
<u>A. Primary Treatment Plants</u>										
SW	Point Edward	.57	51	64.5	35.5	54.5 to 74.5	53	62.8	68.4	43.9 to 81.6
NE	Espanola	.66	60	63.7	35.6	54.5 to 2.9	60	61.7	23.2	55.7 to 67.7
<u>B. Conventional Activated Sludge Plant</u>										
SW	St. Marys	.85	60	6.6	4.8	5.4 to 7.8	60	5.5	3.3	4.6 to 6.3
W Central	Haldimand Caledonia	.5	48	8.8	8.2	6.4 to 11.2	47	26.8	16.9	21.9 to 31.8
Central	Burlington E G	.75	50	20.8	21.6	14.7 to 26.9	49	21.8	40.5	10.2 to 33.4
SE	Sidney Twp	.12	52	13.6	12.8	10.0 to 17.1	46	21.3	25.4	13.8 to 38.9
<u>C. Extended Aeration Plants</u>										
SW	Moore Twp (Corunna)	.32	60	8.4	3.2	7.6 to 9.2	60	10.2	1.9	9.7 to 10.7
SW	Westminster	.25	58	8.3	9.5	5.8 to 10.8	58	10.5	11.8	7.4 to 10.7
W Central	Elora	.083	56	23.5	24.1	17.0 to 29.9	58	29.3	21.2	23.7 to 34.8
W Central	Haldimand Cayuga	.2	47	4.9	3.4	3.9 to 5.9	45	15.5	8.8	12.8 to 18.1
W Central	Paris	.5	36	15.6	10.3	12.1 to 19.1	46	27.9	21.9	21.4 to 34.4
Central	Alliston	.77	55	9.7	9.6	7.1 to 12.3	59	22.7	12.2	19.6 to 25.9
SE	Deseronto	.3	57	19.0	78.5	-1.9 to 39.9	58	23.3	117.2	-7.6 to 54.1
SE	Eganville	.17	58	10.5	15.3	6.4 to 14.5	56	17.6	11.6	14.5 to 20.6
NW	Ignace Twp	.14	46	18.3	14.9	13.9 to 22.7	46	27.0	24.9	19.6 to 34.4

TABLE IV (Cont'd)

CAPACITY LESS THAN 1

BOD

5

SS

REGION	NAME OF PLANTS	CAPACITY	COUNT	MEAN	S.D.	LIMITS	COUNT	MEAN	S.D.	LIMITS
D. <u>Contact Stabilization Plants</u>										
NW	Red Lake	.25	42	14.5	15.4	9.7 to 19.3	43	24.8	39.7	12.6 to 37.0
E. <u>High Rate Activated Sludge Plants</u>										
SW	Meaford	.86	56	8.3	10.2	5.6 to 11.0	60	10.9	9.0	8.6 to 13.2
Central	Bradford	.80	49	17.1	13.4	13.2 to 20.9	49	47.2	99.9	18.5 to 75.8

II. CAPACITY = 1 TO 10

A. <u>Primary Treatment Plants</u>										
SW	Owen Sound	3.0	58	34.6	10.4	31.9 to 37.3	60	32.9	13.5	29.4 to 36.3
W Central	Nanticoke (Port Dover)	2.1	54	87.4	91.7	62.4 to 112.4	54	61.7	58.0	45.9 to 77.5
Central	Midland	1.25	59	50.2	40.8	39.6 to 60.8	58	53.9	28.4	46.4 to 61.3
SE	Cornwall	8.25	53	130.6	69.6	111.4 to 149.8	58	118.7	69.9	100.3 to 137.1
SE	Prescott	1.0	59	39.1	23.7	32.9 to 45.2	59	50.7	22.2	44.9 to 56.5
NW	Fort Frances	2.0	58	45.6	7.2	43.7 to 47.4	60	57.0	14.9	53.1 to 60.8
NW	Thunder Bay N	4.0	160	94.2	21.9	82.6 to 105.9	16	76.9	37.4	57.0 to 96.8
B. <u>Conventional Activated Sludge Plants</u>										
W Central	Cambridge Galt	8.5	60	13.6	10.9	10.8 to 16.4	60	20.8	17.7	16.2 to 25.3
SE	Kingston Twp	2.42	60	59.6	51.7	46.2 to 72.9	60	63.9	59.5	48.6 to 79.3
NE	North Bay	8.0	55	22.7	12.7	19.3 to 26.1	57	32.0	21.3	26.4 to 37.7
N Central	Cambridge Preston	3.7	53	38.3	37.5	28.0 to 48.6	54	33.0	25.0	26.2 to 39.8
SW	Chatham	4.5	60	12.0	9.2	9.6 to 14.4	60	14.8	15.0	11.0 to 18.7
SW	Ingersoll	2.25	55	9.6	5.9	8.1 to 11.2	56	14.6	14.0	10.9 to 18.4

TABLE IV (Cont'd)

SS

BOD₅

II CAPACITY = 1 TO 10

REGION	NAME OF PLANTS	CAPACITY	COUNT	MEAN	S.D.	LIMITS	COUNT	MEAN	S.D.	LIMITS
B.	<u>Conventional Activated Sludge Plants</u>									
SW	Tillsonburg	1.85	55	4.3	2.4	3.7 to 5.0	60	10.9	9.3	8.5 to 13.3
SW	Wallaceburg	1.5	66	6.9	4.2	5.9 to 7.9	60	7.5	5.1	6.2 to 8.7
W Central	Simcoe	2.0	47	11.9	13.1	13.7 to 18.6	48	17.4	10.4	14.4 to 20.5
W Central	Waterloo	6.0	59	16.1	9.6	13.7 to 18.6	60	20.0	11.6	16.2 to 22.1
Central	Burlington D L	2.5	58	13.3	10.2	10.6 to 15.9	59	16.9	13.8	13.3 to 20.5
Central	Halton Hills(George town)	1.5	52	16.4	10.6	13.4 to 19.3	60	20.7	9.6	18.3 to 23.2
SE	Belleville	8.6	59	14.7	5.4	13.3 to 16.1	59	12.9	5.7	11.4 to 14.4
E.	<u>High Rate Activated Sludge Plants</u>									
SE	Carleton	1.2	40	18.8	10.3	15.5 to 22.1	41	24.9	12.1	21.1 to 28.7

III. CAPACITY OVER 10

A.	<u>Primary Treatment Plants</u>									
NE	Sault Ste. Marie	12.0	60	73.0	22.7	67.1 to 78.8	60	56.0	10.1	53.3 to 58.6
B.	<u>Conventional Activated Sludge Plants</u>									
W Central	Brantford	12.5	60	15.5	9.1	13.2 to 17.8	60	20.5	8.2	18.4 to 22.6
W Central	Kitchener	13.5	60	25.3	24.9	18.9 to 31.7	60	22.5	16.9	18.1 to 26.8
E.	<u>High Rate Activated Sludge Plants</u>									
	Sudbury	11.25	58	15.9	7.9	13.8 to 17.9	59	19.5	12.1	13.5 to 17.9

STEP IV

During the analysis at this stage, a few plants were removed due to the non-representative nature of plant type, as well as deficiency of data. For example, the Alliston plant was removed because it was felt by MOE that it did not truly represent Extended Aeration Type; Elora plant was excluded because MOE found some data problems.

The final cells, given in Table V, were tested for homogeneity and it was found, in general, plant data in these cells were homogeneous.

Cells provided in Table V were used to estimate sample size requirements.

TABLE V

FINAL STAGE

I CAPACITY LESS THAN 1 m.g.d.

BOD SS

REGION	NAME OF PLANTS	CAPACITY	COUNT	MEAN	S.D.	LIMITS	COUNT	MEAN	S.D.	LIMITS
A. <u>Primary Treatment Plants</u>										
S W	Point Edward	.57	51	64.5	35.5	54.5 to 74.5	53	62.8	68.4	43.9 to 81.6
N E	Espanola	.66	60	63.7	35.6	54.5 to 2.9	60	61.7	23.2	55.7 to 67.7
B. <u>Activated Sludge Plant</u>										
S W	St. Marys	.85	60	6.6	4.8	5.4 to 7.8	60	5.5	3.3	4.6 to 6.3
W Central	Haldimand Caledonia	.5	48	8.8	8.2	6.4 to 11.2	47	26.8	16.9	21.9 to 31.8
S E	Sidney Twp.	.12	52	13.6	12.8	10.0 to 17.1	46	21.3	25.4	13.8 to 38.9
S W	Meaford	.86	56	8.3	10.2	5.6 to 11.0	60	10.9	9.0	8.6 to 13.2
Central	Bradford	.80	49	17.1	13.4	13.2 to 20.9	49	47.2	99.9	18.5 to 75.8
C. <u>Extended Aeration Plants</u>										
S W	Moore Twp. (Corunna)	.32	60	8.4	3.2	7.6 to 9.2	60	10.2	1.9	9.7 to 10.7
S W	Westminster	.25	58	8.3	9.5	5.8 to 10.8	58	10.5	11.8	7.4 to 10.7
W Central	Haldimand Cayuga	.2	47	4.9	3.4	3.9 to 5.9	45	15.5	8.8	12.8 to 18.1
W Central	Paris	.5	36	15.6	10.3	12.1 to 19.1	46	27.9	21.9	21.4 to 34.4
S E	Deseronto	.3	57	19.0	78.5	-1.9 to 39.9	58	23.3	117.2	-7.6 to 54.1
S E	Eganville	.17	58	10.5	15.3	6.4 to 14.5	56	17.6	11.6	14.5 to 20.6
N W	Ignace Twp	.14	46	18.3	14.9	13.9 to 22.7	46	27.0	24.9	19.6 to 34.4
D. <u>Contact Stabilization Plants</u>										
N W	Red Lake	.25	42	14.5	15.4	9.7 to 19.3	43	24.8	39.7	12.6 to 37.0

II. CAPACITY 1 TO 5 m.g.d.

TABLE V (Cont'd.)

BOD

SS

REGION	NAME OF PLANTS	CAPACITY	COUNT	MEAN	S.D.	LIMITS	COUNT	MEAN	S.D.	LIMITS
A. Primary Treatment Plants										
S W	Owen Sound	3.0	58	34.6	10.4	31.9 to 37.3	60	32.9	13.5	29.4 to 36.3
Central	Midland	1.25	59	50.2	40.8	39.6 to 60.8	58	53.9	28.4	46.4 to 61.3
S E	Prescott	1.0	59	39.1	23.7	32.9 to 45.2	59	50.7	22.2	44.9 to 56.5
N W	Fort Frances	2.0	58	45.6	7.2	43.7 to 47.4	60	57.0	14.9	53.1 to 60.8
B. Conventional Activated Sludge Plants										
W Central	Cambridge Preston	3.7	53	38.3	37.5	28.0 to 48.6	54	33.0	25.0	26.2 to 39.8
S W	Chatham	4.5	60	12.0	9.2	9.6 to 14.4	60	14.8	15.0	11.0 to 18.7
S W	Ingersoll	2.25	55	9.6	5.9	8.1 to 11.2	56	14.6	14.0	10.9 to 18.4
S W	Tillsonburg	1.85	55	4.3	2.4	3.7 to 5.0	60	10.9	9.3	8.5 to 13.3
S W	Wallaceburg	1.5	66	6.9	4.2	5.9 to 7.9	60	7.5	5.1	6.2 to 8.7
W Central	Simcoe	2.0	47	11.9	13.1	13.7 to 18.6	48	17.4	10.4	14.4 to 20.5
Central	Burlington D L	2.5	58	13.3	10.2	10.6 to 15.9	59	16.9	13.8	13.3 to 20.5
Central	Halton Hills(Georgetown)	1.5	52	16.4	10.6	13.4 to 19.3	60	20.7	9.6	18.3 to 23.2
S E	Carleton	1.2	40	18.8	10.3	15.5 to 22.1	41	24.9	12.1	21.1 to 28.7

III CAPACITY 6 TO 10 m.g.d.

REGION	NAME OF PLANTS	CAPACITY	COUNT	MEAN	S.D.	LIMITS	COUNT	MEAN	S.D.	LIMITS
W Central	Cambridge Galt	8.5	60	13.6	10.9	10.8 to 16.4	60	20.8	17.7	16.2 to 25.3
N E	North Bay	8.0	55	22.7	12.7	19.3 to 26.1	57	32.0	21.3	26.4 to 37.7
W Central	Waterloo	6.0	59	16.1	9.6	13.7 to 18.6	60	19.1	11.6	16.2 to 22.1
S E	Belleville	8.6	59	14.7	5.4	13.3 to 16.1	59	12.9	5.7	11.4 to 14.4

IV. CAPACITY OVER 10. m.g.d.

A. <u>Primary Treatment Plants</u>										
N E	Sault Ste Marie	12.0	60	73.0	22.7	67.1 to 78.8	60	56.0	10.1	53.3 to 58.6
B. <u>Conventional Activated Sludge Plants</u>										
W Central	Brantford	12.5	60	15.5	9.1	13.2 to 17.8	60	20.5	8.2	18.4 to 22.6
W Central	Kitchener	13.5	60	25.3	24.9	18.9 to 31.7	60	22.5	16.9	18.1 to 26.8
E	Sudbury	11.25	58	15.9	7.9	13.8 to 17.9	59	19.5	12.1	13.5 to 17.9

STEP V

As can be seen from the final stage of cell development, (Table V) only 9 cells could be constructed; out of 9 cells only 7 cells could be used for sample size determination, since two cells had only one plant in each.

Calculation of sample size for each cell was conducted in two stages. In the first stage, sample size was determined based on all the plant data. Tables were prepared for each cell for various confidence levels and tolerance errors. (Table VI). In addition, confidence level was found for the given tolerance if sample size was to be 12 for the cell.

In the second stage, mean value of each plant was used to represent the plant, in the cell, and sample size was determined from the representative mean values. Tables were constructed for various levels of confidence and tolerance errors. (Table VII). It should be noted that in the second stage, small sample sizes were obtained due to removal of all plant data variation by substituting mean values. Opinions were expressed by MOE personnel that these mean values could be used for monitoring purposes. For example, comparing Table VI(E) and Table VII(E), when the mean values were substituted to represent plant data, confidence level changed from 28% to 60% for a sample size of 12 with 10% of tolerance error.

TABLE VI
STAGE I

Sample size distribution is calculated by the following expression:

$$n = \frac{z^2 \sigma^2}{e^2}$$

where n = sample size
 σ = standard deviation
 e = tolerance error
 (In this case percent of the mean value)
 z = values from normal distribution table, related to
 confidence level
 (In this case 95%, 90%, and 75% are considered)
 C.L.= confidence level based on Z values

SAMPLE SIZE DISTRIBUTIONS:

<div>e \ C L</div>	95%	90%	75%	IF n = 12, Confidence Limit is listed below
10%		n		
20%				
40%				

TABLE VI(A)

PRIMARY TREATMENT PLANTS

CAPACITY = LT 1 mgd

BOD

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>	<u>95% C L for Mean</u>
Prince Edward	51	64.47	35.49	54.49 - 74.45
Espanola	60	61.97	33.96	53.60 - 70.74
TOTAL	111	63.12	34.53	56.62 - 69.61

SAMPLE SIZE DISTRIBUTIONS:

<div> <div>C L</div> <div>e</div> </div>	95%	90%	75%	IF n = 12, Confidence Limit is listed below
10%	107	75	37	49%
20%	29	20	10	80%
40%	7	3	2	98%

TABLE VI(B)

PRIMARY TREATMENT PLANTS

CAPACITY = LT 1 mgd

SS

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>	<u>95% C L for Mean</u>
Point Edward	52	55.08	40.06	43.93 - 66.23
Espanola	60	61.68	23.17	55.70 - 67.67
TOTAL	112	58.62	32.15	52.60 - 64.64

SAMPLE SIZE DISTRIBUTIONS:

<div>C L</div> <div>e</div>	95%	90%	75%	IF n = 12, Confidence Limit is listed below
10%	108	75	37	49%
20%	29	20	10	80%
40%	7	5	2	99.8%

TABLE VI(C)

ACTIVATED SLUDGE PLANTS

CAPACITY = LT 1 mgd

BOD

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>	<u>95% C L for Mean</u>
St Marys	60	6.55	4.76	5.32 - 7.78
Haldimand Caledonia	48	8.73	8.19	6.35 - 11.11
Sidney Twp	50	13.36	12.77	9.73 - 16.99
Meaford	56	8.25	10.10	5.54 - 10.96
Bradford	50	16.74	13.32	12.95 - 20.53
TOTAL	264	10.53	10.77	9.22 - 11.83

SAMPLE SIZE DISTRIBUTIONS:

<div>C L</div> <div>e</div>	95%	90%	75%	IF n = 12, Confidence Limit is listed below
10%	254	178	87	33%
20%	100	70	35	50%
40%	25	18	9	85%

TABLE VI(D)

ACTIVATED SLUDGE PLANTS

CAPACITY = LT 1 mgd

SS:

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>	<u>95% C L for Mean</u>
St Marys	60	5.40	3.25	4.56 - 6.24
Haldimand Caledonia	47	26.77	16.82	21.83 - 31.70
Sidney Twp	43	17.63	7.14	15.43 - 19.83
Meaford	60	10.88	8.94	8.57 - 13.19
Bradford	49	32.92	30.25	24.23 - 41.61
TOTAL	259	17.78	18.83	15.48 - 20.09

SAMPLE SIZE DISTRIBUTIONS:

<div>C L</div> <div>e</div>	95%	90%	75%	IF n = 12, Confidence Limit is listed below
10%	248	174	86	33%
20%	108	75	37	48%
40%	27	19	9	80%

EXTENDED AERATION PLANTS

CAPACITY = LT 1 mgd

BOD

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>	<u>95% C L for Mean</u>
Moore Twp Corunna	60	8.32	3.14	7.51 - 9.13
Westminster	59	8.32	9.41	5.87 - 10.77
Haldimand Cayuga	47	4.83	3.33	3.84 - 5.81
Paris	36	15.53	10.27	12.05 - 19.00
Deseronto	57	8.51	4.72	7.26 - 9.76
Eganville	58	10.41	15.29	6.39 - 14.43
Ignace Twp	46	18.28	14.85	13.87 - 22.69
TOTAL	363	10.21	10.56	9.12 - 11.30

SAMPLE SIZE DISTRIBUTIONS:

<div>C L e</div>	95%	90%	75%	IF n = 12, Confidence Limit is listed below
10%	354	248	122	28%
20%	103	72	35	45%
40%	24	17	8	99%

TABLE VI(F)

EXTENDED AERATION PLANTS

CAPACITY = LT 1 mgd

SS

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>	<u>95% C L for Mean</u>
Moore Twp Corunna	60	10.17	1.86	9.69 - 10.65
Westminster	59	10.46	11.61	7.43 - 13.48
Haldimand Cayuga	45	15.42	8.78	12.79 - 18.06
Paris	46	27.85	21.83	21.36 - 34.33
Deseronto	58	7.86	3.49	6.95 - 8.78
Eganville	56	17.50	11.57	14.40 - 20.60
Ignace Twp	46	26.98	24.85	19.60 - 34.36
TOTAL	370	15.89	15.49	14.31 - 17.47

SAMPLE SIZE DISTRIBUTIONS:

<div>C L</div> <div>e</div>	95%	90%	75%	IF n = 12, Confidence Limit is listed below
10%	351	258	121	28%
20%	91	64	31	53%
40%	23	16	8	84%

PRIMARY TREATMENT PLANTS

CAPACITY = 1 - 5 mgd

BOD:

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>	<u>95% C L for Mean</u>
Owen Sound	58	34.54	10.33	31.82 - 37.25
Midland	59	44.98	13.81	41.38 - 48.58
Prescott	58	39.17	23.82	32.91 - 45.43
Fort Frances	58	45.50	7.10	43.63 - 47.37
TOTAL	233	41.06	15.69	39.04 - 43.09

SAMPLE SIZE DISTRIBUTIONS:

<div> <div>C L</div> <div>e</div> </div>	95%	90%	75%	IF n = 12, Confidence Limit is listed below
10%	227	159	67	34%
20%	14	10	5	94%
40%	4	2	1	99.9%

PRIMARY TREATMENT PLANTS

CAPACITY = 1 - 5 mgd

SS

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>	<u>95% C L for Mean</u>
Owen Sound	60	32.82	13.41	29.35 - 36.28
Midland	58	51.48	25.73	44.72 - 58.25
Prescott	58	50.60	22.38	44.72 - 56.48
Fort Frances	60	56.92	14.81	53.09 - 60.74
TOTAL	236	47.90	21.59	45.13 - 50.67

SAMPLE SIZE DISTRIBUTIONS:

<div>C L</div> <div>e</div>	95%	90%	75%	IF n = 12, Confidence Limit is listed below
10%	225	158	78	34%
20%	19	14	7	85%
40%	5	3	2	99%

TABLE VI(I)

ACTIVATED SLUDGE PLANTS

CAPACITY = 1 - 5 mgd

BOD

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>	<u>95% C L for Mean</u>
Chatham	60	11.97	9.18	9.60 - 14.34
Ingersoll	56	9.55	5.77	8.01 - 11.10
Tillsonburg	55	4.27	2.35	3.64 - 4.91
Wallaceburg	59	6.64	4.18	5.55 - 7.73
Simcoe	52	11.46	12.50	7.98 - 14.94
Burlington D L	58	13.22	10.16	10.55 - 15.90
Halton Hills	52	16.31	10.52	13.38 - 19.24
Cambridge Hespler	57	37.53	36.24	27.91 - 47.14
Carleton Place	56	19.80	12.40	16.48 - 23.13
TOTAL	505	14.53	17.44	13.01 - 16.06

SAMPLE SIZE DISTRIBUTIONS:

<div>C L e</div>	95%	90%	75%	IF n = 12, Confidence Limit is listed below
10%	478	335	165	24%
20%	138	97	48	42%
40%	25	18	9	82%

TABLE VI(J)

ACTIVATED SLUDGE PLANTS

CAPACITY = 1 - 5 mgd

SS

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>	<u>95% C L for Mean</u>
Chatham	60	14.77	14.95	10.91 - 18.63
Ingersoll	57	14.74	13.90	11.05 - 18.42
Tillsonburg	60	10.88	9.26	8.49 - 13.28
Wallaceburg	60	6.45	3.92	5.44 - 7.46
Simcoe	53	17.38	9.97	14.63 - 20.13
Burlington D L	59	16.83	13.76	13.24 - 20.42
Halton Hills	60	20.68	9.59	18.21 - 23.16
Cambridge Hespler	59	33.76	25.01	27.24 - 40.28
Carleton Place	57	25.88	13.39	22.32 - 29.43
TOTAL	525	17.88	15.68	16.54 - 19.23

SAMPLE SIZE DISTRIBUTIONS:

<div>C L</div> <div>e</div>	95%	90%	75%	IF n = 12, Confidence Limit is listed below
10%	510	358	176	22%
20%	74	52	25	56%
40%	18	13	6	88%

ACTIVATED SLUDGE PLANTS

CAPACITY = 6 - 10 mgd

BOD

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>	<u>95% C L of Mean</u>
Waterloo	59	16.08	9.51	13.61 - 18.56
Belleville	59	14.64	5.39	13.23 - 16.05
North Bay	55	22.67	12.66	19.25 - 26.09
Cambridge Galt	60	13.58	10.86	10.78 - 16.39
TOTAL	233	16.63	10.45	15.28 - 17.98

SAMPLE SIZE DISTRIBUTIONS:

<div>e \ C L</div>	95%	90%	75%	IF n = 12, Confidence Limit is listed below
10%	224	157	77	35%
20%	38	27	13	73%
40%	9	7	3	96%

ACTIVATED SLUDGE PLANTS

CAPACITY = 6 - 10 mgd

SS

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>	<u>95% C L of Mean</u>
Waterloo	60	19.08	11.53	16.10 - 22.06
Belleville	59	12.85	5.68	11.37 - 14.33
North Bay	57	32.00	21.22	26.37 - 37.63
Cambridge Galt	60	20.73	17.65	16.17 - 25.30
TOTAL	236	21.06	16.55	18.94 - 23.19

SAMPLE SIZE DISTRIBUTIONS:

<div>C L</div> <div>e</div>	95%	90%	75%	IF n = 12, Confidence Limit is listed below
10%	227	159	78	35%
20%	59	42	20	62%
40%	15	10	5	92%

TABLE VI (M)

ACTIVATED SLUDGE PLANTS

CAPACITY = OVER 10 mgd

BOD

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>	<u>95% C L for Mean</u>
Brantford	60	15.45	9.04	13.11 - 17.79
Kitchener	60	21.93	9.38	19.51 - 23.36
Sudbury	58	15.86	7.88	13.79 - 17.93
TOTAL	178	17.77	9.24	16.40 - 19.14

SAMPLE SIZE DISTRIBUTIONS:

<div>C L</div> <div>e</div>	95%	90%	75%	IF n = 12, Confidence Limit is listed below
10%	171	120	59	40%
20%	26	18	9	82%
40%	6	5	2	99.9%

TABLE VI(N)

ACTIVATED SLUDGE PLANTS

CAPACITY = OVER 10 mgd

SS

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>	<u>95% C L for Mean</u>
Brantford	60	20.48	8.13	18.38 - 22.58
Kitchener	60	22.42	16.89	18.05 - 26.78
Sudbury	59	15.66	8.41	13.47 - 17.85
TOTAL	179	19.54	12.15	17.75 - 21.33

SAMPLE SIZE DISTRIBUTIONS:

<div>C L</div> <div>e</div>	95%	90%	75%	IF n = 12, Confidence Limit is listed below
10%	172	120	59	40%
20%	37	26	13	73%
40%	9	6	3	96%

TABLE VII

STAGE II

Confidence levels are calculated from the following expression:

$$t_{\alpha} = \frac{e\sqrt{n}}{s}$$

where

n = sample size

s = standard deviation

e = tolerance error

(In this case percent of the mean value)

t_{α} = is percentage point from the t-distribution.

which is used to calculate confidence level.

C.L. = confidence level based on t values

SAMPLE SIZE DISTRIBUTIONS:

<div><div>n</div><div>e</div></div>	6	12	26	52
10%		CL		
20%				
40%				

: 40 :
TABLE VII(A)

PRIMARY TREATMENT PLANTS

CAPACITY = LT 1 mgd

BOD

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>
Point Edward		64.47	35.49
Espanola		61.97	33.96
TOTAL	2	63.22	1.77

SAMPLE SIZE DISTRIBUTIONS:

<div> <div>n</div> <div>e</div> </div>	6	12	26	52
10%				
20%				
40%				

NOTE: Blank spaces mean values exceed 99.9%.

PRIMARY TREATMENT PLANTS

CAPACITY = LT 1 mgd

SS

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>
Point Edward		55.08	40.06
Espanola		61.68	23.17
TOTAL	2	58.38	4.66

SAMPLE SIZE DISTRIBUTIONS:

<div> n e </div>	6	12	26	52
10%	96%	99.9%		
20%				
40%				

NOTE: Blank spaces mean values exceed 99.9%.

TABLE VII(C)

ACTIVATED SLUDGE PLANTS

CAPACITY = LT 1 mgd

BOD

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D</u>
St Marys		6.55	4.76
Haldimand Caledonia		8.73	8.19
Sidney Twp		13.36	12.77
Meaford		8.25	10.10
Bradford		16.74	13.32
TOTAL	5	10.73	4.20

SAMPLE SIZE DISTRIBUTIONS:

<div>n e</div>	6	12	26	52
10%	46%	60%	78%	99.9%
20%	78%	89%	99.8%	
40%	99.5%	99.9%		

NOTE: Blank spaces mean values exceed 99.9%.

TABLE VII(C)

ACTIVATED SLUDGE PLANTS

CAPACITY = LT 1 mgd

SS

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>
St Marys		5.40	3.25
Haldimand Caledonia		26.77	16.82
Sidney Twp		17.63	7.14
Meaford		10.88	8.94
Bradford		32.92	30.25
TOTAL	5	18.72	11.25

SAMPLE SIZE DISTRIBUTIONS:

<div> <div>n</div> <div>e</div> </div>	6	12	26	52
10%	40%	48%	62%	78%
20%	52%	85%	92%	99.9%
40%	82%	99.6%	99.9%	

NOTE: Blank spaces mean values exceed 99.9%.

TABLE VII(E)

EXTENDED AERATION PLANTS

CAPACITY = LT 1 mgd

BOD

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>
Moore Twp Corunna		8.32	3.14
Westminster		8.32	9.41
Haldimand Cayuga		4.83	3.33
Paris		15.53	10.27
Deseronto		8.51	4.72
Eganville		10.41	15.29
Ignace Twp		18.28	14.85
TOTAL	7	10.60	4.68

SAMPLE SIZE DISTRIBUTIONS:

<div>n e</div>	6	12	26	52
10%	35%	60%	78%	99.9%
20%	66%	86%	99%	99.9%
40%	99.5%	99.9%		

NOTE: Blank spaces mean values exceed 99.9%.

TABLE VII(F)

EXTENDED AERATION PLANTS

CAPACITY = LT 1 mgd

SS

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>
Moore Twp Corunna		10.17	1.86
Westminster		10.46	11.61
Haldimand Cayuga		15.42	8.78
Paris		27.85	21.83
Deseronto		7.86	3.49
Eganville		17.50	11.57
Ignace Twp		26.98	24.85
TOTAL	7	16.61	8.08

SAMPLE SIZE DISTRIBUTIONS:

<div>n</div> <div>e</div>	6	12	26	52
10%	47%	49%	75%	88%
20%	60%	82%	95%	99.5%
40%	88%	98.8%		

NOTE: Blank spaces mean values exceed 99.9%.

TABLE VII(G)

PRIMARY TREATMENT PLANTS

CAPACITY = 1 - 5 mgd

BOD

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>
Owen Sound		34.54	10.33
Midland		44.98	13.81
Prescott		39.17	23.82
Fort Frances		45.50	7.10
TOTAL	4	41.05	5.20

SAMPLE SIZE DISTRIBUTIONS:

<div>n</div> <div>e</div>	6	12	26	52
10%	88%	99.8%		
20%	98.8%			
40%				

NOTE: Blank spaces means values exceed 99.9%.

: 47 :

TABLE VII(H)

PRIMARY TREATMENT PLANTS

CAPACITY = 1 - 5 mgd

SS

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>
Owen Sound		32.82	13.41
Midland		51.48	25.73
Prescott		50.60	22.38
Fort Frances		56.92	14.81
TOTAL	4	47.96	10.47

SAMPLE SIZE DISTRIBUTIONS:

<div>n</div> <div>e</div>	6	12	26	52
10%	78%	85%	97%	99.9%
20%	92%	99.9%		
40%	99.9%			

NOTE: Blank spaces mean values exceed 99.9%.

ACTIVATED SLUDGE PLANTS

CAPACITY = 1 - 5 mgd

BOD

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>
Chatham		11.97	9.18
Ingersoll		9.55	5.77
Tillsonburg		4.27	2.35
Wallaceburg		6.64	4.18
Simcoe		11.46	12.50
Burlington D L		13.22	10.16
Halton Hills		16.31	10.52
Cambridge Hespler		37.53	36.24
Carleton Place		19.80	12.40
TOTAL	9	17.86	19.20

SAMPLE SIZE DISTRIBUTIONS:

<div> <div>n</div> <div>e</div> </div>	6	12	26	52
10%	18%	24%	37%	47%
20%	35%	47%	63%	82%
40%	73%	84%	99.5%	99.9%

NOTE: Blank spaces mean values exceed 99.9%.

: 49 :
TABLE VII(J)

ACTIVATED SLUDGE PLANTS

CAPACITY = 1 - 5 mgd

SS

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>
Chatham		14.77	14.95
Ingersoll		14.74	13.90
Tillsonburg		10.88	9.26
Wallaceburg		6.45	3.92
Simcoe		17.38	9.97
Burlington D L		16.83	13.76
Halton Hills		20.68	9.59
Cambridge Hespler		33.76	25.01
Carleton Place		25.88	13.39
TOTAL	9	17.89	8.11

SAMPLE SIZE DISTRIBUTIONS:

<div>n e</div>	6	12	26	52
10%	32%	53%	67%	90.5%
20%	66%	84%	97%	99.5%
40%	93%	98.9%		

NOTE: Blank spaces mean values exceed 99.9%.

: 50 :

TABLE VII(K)

ACTIVATED SLUDGE PLANTS

CAPACITY = 6 - 10 mgd

BOD

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>
Waterloo		16.08	9.51
Belleville		14.64	5.39
North Bay		22.67	12.66
Cambridge Galt		13.58	10.86
TOTAL	4	16.74	4.08

SAMPLE SIZE DISTRIBUTIONS:

<div>n</div> <div>e</div>	6	12	26	52
10%	62%	82%	95%	99.95%
20%	89%	98.3%	99.99%	
40%	99.2%			

NOTE: Blank spaces mean values exceed 99.9%.

TABLE VII(L)

ACTIVATED SLUDGE PLANTS

CAPACITY = 6 - 10 mgd

SS

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>
Waterloo		19.08	11.53
Belleville		12.85	5.68
North Bay		32.00	21.22
Cambridge Galt		20.73	17.65
TOTAL	4	21.17	7.98

SAMPLE SIZE DISTRIBUTIONS:

<div> <div>n</div> <div>e</div> </div>	6	12	26	52
10%	45%	70%	78%	95%
20%	75%	91%	98.8%	
40%	96%	99.8%		

NOTE: Blank spaces mean values exceed 99.9%.

TABLE VII (M)

ACTIVATED SLUDGE PLANTS

CAPACITY = OVER 10 mgd

BOD

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>
Brantford		15.45	9.04
Kitchener		21.93	9.38
Sudbury		15.86	7.88
TOTAL	3	17.78	3.60

SAMPLE SIZE DISTRIBUTIONS:

<div>n</div> <div>e</div>	6	12	26	52
10%	70%	89%	99.8%	
20%	94%	99.4%		
40%	99.5%			

NOTE: Blank spaces mean values exceed 99.9%.

TABLE VII(N)

ACTIVATED SLUDGE PLANTS

CAPACITY = OVER 10 mgd

SS

<u>Plants</u>	<u>Count</u>	<u>Mean</u>	<u>S.D.</u>
Brantford		20.48	8.13
Kitchener		22.42	16.89
Sudbury		15.66	8.41
TOTAL	3	19.52	3.48

SAMPLE SIZE DISTRIBUTIONS:

<div>n</div> <div>e</div>	6	12	26	52
10%	78%	91%	99.9%	
20%	91%	99.8%		
40%				

NOTE: Blank spaces mean values exceed 99.9%.

5. APPENDIX

Methodology

1. Comparison of Two Sample Means

When dealing with samples from populations with unknown variances, the normal test cannot be applied to compare two means. However, under the assumptions,

- a) both samples are drawn randomly
- b) both populations are normal
- c) both populations have the same variance

then the following t-statistics can be used to compare means

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{1}{n_1} + \frac{1}{n_2}} \sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 1}}}$$

Where n_1 and n_2 are sample sizes for each sample respectively.

If the third assumption above i.e. both populations have the same variance cannot be met, then the appropriate statistics for testing the hypothesis is,

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

Where the number of degrees of freedom can be obtained from the following approximation:

$$\frac{1}{n} = \frac{1}{n_1 - 1} \left[\frac{\frac{S_1^2}{n_1}}{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} \right] + \frac{1}{n_2 - 1} \left[\frac{\frac{S_1^2}{n_1}}{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} \right]^2$$

2. Comparison of More Than Two Sample Means

A technique called Analysis of Variance is used to compare three or more means. In addition to comparing means, this method also attempts to analyze the total variation of a response by decomposing it into independent and meaningful portions attributable to each of the independent variable and to chance variation.

The analysis of variance is developed under a set of rigid assumptions:

- (i) Treatment combinations are normally distributed with common variance
- (ii) the treatment effects are additive
- (iii) the experimental errors are independent and are normally distributed.

Whenever any of these assumptions are not met, the statistical test (F-test) cannot be employed to yield valid inferences. It is not uncommon, however, to encounter experimental work where departure from these assumptions exists. In such a situation, the analysis of variance can sometimes still be applied after a transformation of data.

Analysis of variance technique - 'methodology' is given in most of the standardized text on "Statistical Methods" or "Statistical Analysis".

3. Multiple Comparison Analysis

Analysis of variance provides only the statistics necessary for significant testing of the Means. Multiple Comparison Analysis method helped to compare plants and group them according to Duncan, Scheffe or Tukey Methods. In this case most of the times Scheffe Method was used to compare and develop groups of various plants.

4. Sample Size

Sample size distribution is determined from the following expression:

$$n = \frac{z^2 \sigma^2}{E^2} \text{ or } \frac{t^2 S^2}{E^2}$$

Where:

σ^2 is population variance, if it is unknown then the sample variance S^2 can be used as an estimate of σ^2 in determining the sample size.

Z is a value depending upon confidence level required and can be determined from the normal distribution.

E is tolerance error and may be defined as:

$$E = \bar{X} - \mu \text{ i.e. difference}$$

between the calculated mean and an actual mean.

A question frequently asked of statistician is, "How large a sample is needed for this experiment?" The question is deceptively simple, but the answer is hard to find. Before the statistician can provide anything better than an "educated guess", he must retaliate with general question, the answers to which should help him to attack the problem. For example to determine the sample size some of the information needed is as follows:-

- (a) Statement of Hypothesis?
- (b) Confidence Level (i.e. to find Z-value in the expression).
- (c) What is variability in data (i.e. σ^2 or S^2 values)
- (d) How large a difference, experiments can tolerate or what width confidence interval experiments can tolerate (i.e. E value).

When answer to these questions and other questions are provided by the researcher, the statistician can be of help in determining the needed sample size.

6. REFERENCES

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